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HELICOPTER NOISE CONTOUR DEVELOPMENT TECHNIQUES AND DIRECTIVITY--ETC(U)

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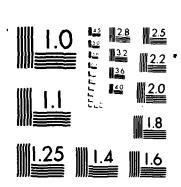
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US Department of Transportation

Federal Aviation Administration Helicopter Noise Contour Development Techniques and Directivity Analysis.

Office of Environment And Energy Washington, D.C. 20591 DA Preliminary Repert.

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September 1980

By J. Steven Newman

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1.0 INTRODUCTION

This paper briefly summarizes techniques which have been developed for use in creating helicopter air-to-ground, noise-distance relationships. Discussion is provided concerning FAA efforts to establish an accurate and practical method (which considers source directivity) for modeling the noise impact associated with helicopter operations. Plots of normalized directivity vectors are provided for eight helicopters in various modes of flight.

2.0 REVIEW OF METHODOLOGIES FOR DEVELOPING HELICOPTER AIR-TO-GROUND, NOISE/DISTANCE CURVES FOR USE IN GENERATING NOISE CONTOURS

The following paragraphs describe methodologies for developing air-to-ground noise/distance curves for use in generating helicopter noise contours using measured data along with SAE-ARP-866A atmospheric absorption attenuation coefficients, the spherical spreading law, and various assumptions concerning the effect of distance on the flyover 10-dB down time history.

2.1 Method 1 - U.S. Air Force

Jerry Speakman¹ of the U.S. Air Force Wright Patterson Aero-Medical Center has developed a set of air-to-ground noise exposure versus distance curves based on FAA noise data reported in 1977 by True and Rickley and adjusted to agree with FAA data reported in 1979 by Newman and Rickley. The USAF methodology begins with the acoustical spectra

from the time at which the maximum perceived noise level (PNLM) occured. This spectrum is extrapolated to distances using the spherical spreading law and atmospheric absorption corrections provided in SAE-ARP-866A. This spectrum is used along with a 6 dB per decade factor (to account for the change in event duration) to arrive at a value of Noise Exposure Level (NEL), or Effective Perceived Noise Level (EPNL).

2.2 Method 2 - U.S. Army

Paul Schomer² of the U.S. Army Construction Engineering Research
Laboratory (CERL) has developed a procedure using data measured by CERL
at Ft. Rucker during 1974. The CERL method starts with the spectra for
each one-half second sample of the entire flyover time history (noise
floor limited). Each spectrum is extrapolated to distances using the
spherical spreading law, along with ARP-866A. The decayed time history
is then used to compute EPNL (or NEL) at distance. Use of this
methodology is appropriate out to slant distances of approximately
3,000 feet. The recorded time history is not long enough to project
beyond 3,000 feet. CERL data (unpublished) have shown a net 7 dB/decade
attenuation between 0 and 1,000' slant ranges, and 10 dB/decade
attenuation between 1,000' and 5,000' slant ranges.

2.3 Nethod 3 - FAA, Level Flyovers 300 Feet to 2,500 Feet

the June 1980 FAA noise measurement program, level flyovers were conducted at constant speeds for the following altitudes: 300', 500', 700', 1,000', 1,500', 2,000', and 2,500'. Data were recorded for nine

microphone locations and also measured using a precision integrating sound level meter (PISLM) at a single location. The PISLM data have been plotted versus test target altitude and provided in a preliminary report, FAA-AEE-80-34. These data (not corrected to standard T, R.H.), can be used to develop helicopter noise contours for slant distances between 300' and 2,500'. Extrapolation of these data can also be accomplished for longer slant distances.

3.0 DISCUSSION OF TECHNIQUES UNDER DEVELOPMENT BY THE FAA

The June 1978 FAA helicopter noise measurement program provided data reported in FAA-AEE-79-3, prepared by E. J. Rickley of the DOT, Transportation Systems Center (TSC) Noise Measurement and Assessment Laboratory in concert with this author. While FAA-AEE-79-3 was principally concerned with noise certification aspects of the measured data, a follow-on or Phase II report (also an FAA-TSC collaboration) is in preparation which will specifically address helicopter noise contours, source directivity, sound level time histories, and frequency spectra.

The processing of data included considerations for developing Noise Exposure Level (NEF) and Day-Night Sound Level (Ldn) noise contours as well as Time Above (TA) contours. The TA requirements mandated that sound level data versus distance and directivity angle be generated. These level/distance/directivity data have been developed for two directivity angles: (1) the elevation angle formed between the slant range ray (SR) and the ground surface, and (2) the angle between the SR and the helicopter flight path. Data have been generated for takeoffs, approaches, and level flyovers for centerline as well as sideline sites.

The "as measured" spectrum for the helicopter position for each 10 degree increment in elevation angle (from the centerline center microphone location) was adjusted to standard day temperature and relative humidity (77°F, 70 percent) absorption conditions. The spectrum was indexed by the two angles identified above and the slant distance (spherical coordinates). The sound pressure level (SPL) values were then adjusted to distances between 200 feet and 20,000 feet (holding the angles constant) in accordance with the spherical spreading law and consideration of absorption along the extended path. No adjustment was made for excess ground attenuation.

The generated data files provide the means to create a three-dimensional directivity/distance/level model for use in TA and noise contour development. The development of NEL values for (each) location on the ground will require construction of a dB(A) time history using the multi-angle/distance indexed dB(A) values associated with increments along the helicopter flight path. This procedure would also require development of an interpolation routine to assign values to angle-pairs not stored in the data file.

In restrospect, this methodology (clearly more comprehensive than others) has immense computational requirements which restrict its usefulness. While unrealistic as an operational component of a noise contour generating computer model such as the FAA Integrated Noise Model (INM), it may be feasible to construct a separate model for use in computing noise exposure for a limited number of grid locations. This

model can be used to compute NEL for various angle-pairs. In turn, a curve or algorithm could be fit to these data providing NEL as a function of CPA distance and CPA elevation angle (for sideline locations).

A plan under consideration might use the complex data files described above to develop NEL versus distance information for the centerline-center microphone location as the fundamental contour generating data base. Using dB(A) sideline directivity information similar to that presented in the next section it may be possible to generate a CPA-elevation angle correction (for sideline locations) to the centerline-center NEL-distance data.

4.0 HELICOPTER NOISE DIRECTIVITY ANALYSES

The plots shown in this section are samples of helicopter directivity characteristics generated as part of the Phase II reduction of data acquired in the 1978 FAA Helicopter Noise Measurement Program. The diagrams provide the two-dimensional directivity within the vertical plane coincident with the helicopter ground track. A sound level reference semi-circle corresponding to the lowest dB(A) directivity value is provided on each plot. The vector lengths outside the semi-circle correspond linearly to change in level, where 1 cm = 1 dB. A scale is provided to assure proper interpretation in the event length distortion occurs in reproducing the plots.

The angles in each plot increase clockwise from the helicopter flight path extension ahead of the helicopter. The first vector angle is identified in each case and subsequent vectors represent approximately

The vector lengths represent the sound level normalized to a distance of 500 feet. This is hereafter referred to as the normalized directivity (ND). For an observer on the ground, the "lower angle" vectors (near 30° or near 150°) will effectively shrink due to increased path length. Assuming only spherical spreading (additional absorption being small), the 30° and 150° vectors would diminish by 6 dB or 6 cm. Other vector length adjustments for a ground observer during level flyover include:

Level Adjustment for <u>Ground Observer</u>	
6 dB 3.8 dB 2.3 dB 1.2 dB .5 dB .1 dB 0 dB	

The vector length adjustments for takeoff and approach would be very close to those shown above.

The directivity envelope seen by a ground observer (GO) is shown on each plot. These diagrams dramatically show the dominance of different melicopter noise sources at different angles as well as their relative intensity levels. For example, the pronounced frontal lobe exhibited by the Su-3300 (Fuma) possibly suggests that the strong forward radiated compressor whine dominates the resulting NEL value. On the other example, the SA-341G (Gazelle) exhibits a comparatively weak forward maintain component but a dominate tail rotor influence. The Sikorsky tool is seen to be nearly an omnidirectional source dominated by main

rotor influences. The following sections give a very brief qualitative assessment of observed directivity characteristics. At this point, no attempt will be made to mathematically model the directivity patterns as monopoles or dipoles or combinations of these or other functions. The matter of identifying the noise generating mechanism associated with various directivity lobes also remains to be addressed. The abbreviations used below include:

ND: Normalized Directivity (to a distance of 500 feet)

GO: Ground Observer Directivity

CPA: Closest Point of Approach

4.1 Bell 212

Silver St. C. Comment of Silver St. Comments of the St. Comments o

The directivity characteristics exhibited by the Bell 212 are discussed below:

Takeoff (Figure 4.1.1)

- ND Pattern: Leading, moderate width

- ND MAX: Near 60 degrees

- GO Pattern: Leading, moderate width

- GO MAX: Near 70 degrees

Approach (Figure 4.1.2)

- ND Pattern: Moderate-narrow width leading
- ND MAX: Near 30 degrees
- GO Pattern: Very narrow width, highly directive,
 leading
- 60 MAX: Near 60 degrees

Level Flyover (Figure 4.1.3)

- ND Pattern: Moderate width, leading
- ND MAX: Near 30 degrees
- GO Pattern: Moderate-narrow lobe, leading
- GO MAX: Near 60 degrees

4.2 SA-330J (Puma)

faceoff (Figure 4.2.1)

- NO Pattern: Approximately omnidirectional
- ND MAX: Near 50 degrees
- 60 Pattern: Wide lobe
- GO MAX: Near CPA (90 degrees)

Approach (Figure 4.2.2)

- 10 Pattern: Highly directive, ahead of SA-330J
- NO MAX: Near 30 degrees
- GO Pattern: Wide, leading, rapidly diminishing after CPA
- GU MAX: Near 30 degrees

Level Flyover (Figure 4.2.3)

- ND Pattern: Ahead of helicopter, moderate width
- ND MAX: Near 40 degrees
- GO Pattern: Also leading
- GO MAX: 50 degrees

4.3 <u>S-61</u>

Takeoff (Figure 4.3.1)

- ND Pattern: Approximately omnidirectional
- ND MAX: Approximately 70 degrees
- GO Pattern: Very wide
- GO MAX: Close to CPA

Approach (Figure 4.3.2)

- ND Pattern: Wide leading
- ND MAX: Approximately 80 degrees
- GO Pattern: Narrow
- GO MAX: Near CPA

Takeoff (Figure 4.3.3)

- ND Pattern: Very wide teardrop
- ND MAX: Near 70 degrees
- GO Pattern: Wide teardrop
- GO MAX: Near CPA

4.4 BO-105

Takeoff (Figure 4.4.1)

- ND Pattern: Sharp forward lobe
- NO HAX: near 40 degrees
- GO Pattern: Narrow leading lobe
- GO MAX: Near 50 degrees

Approach (Figure 4.4.2)

- ND Pattern: Broad irregular leading
- ND MAX: Near 30 degrees
- GO Pattern: Broad irregular leading
- GO MAX: Near 50 degrees

Level Flyover (Figure 4.4.3)

- ND Pattern: Moderate leading
- ND MAX: Near 50 degrees
- GO Pattern: Narrow-moderate leading lobe
- GO MAX: Near 60 degrees

4.5 CH-53

Takeoff (Figure 4.5.1)

- ND Pattern: Very irregular broad leading
- NO MAX: Near CPA
- GO Pattern: Irregular broad leading
- GO MAX: Near CPA

Approach (Figure 4.5.2)

- ND Pattern: Sharp leading lobe at 30 degrees
 medium width lobe at CPA
 generally irregular
- NU MAX: Near 30 degrees
- GO Pattern: Narrow lobe centered on CPA
- GO MAX: Near CPA

Level Flyover (Figure 4.5.3)

- ND Pattern: Strong broad forward lobe
- ND MAX: Near 40 degrees
- GO Pattern: Broad irregular lobe leading
- GO MAX: Near 70 degrees

4.6 SA-341G

Takeoff (Figure 4.6.1)

- ND Pattern: Very irregular, strong rear lobe
- ND MAX: Near 140 degrees
- GO Pattern: Very irregular, strong rear lobe
- GO MAX: Near 120 degrees

Approach (Figure 4.6.2)

- ND Pattern: Generally omnidirectional with rear quadrant emphasis
- ND MAX: Near 110 degrees
- GO Pattern: Sharp rear lobe
- UU MAX: Near 110 degrees

Level Flyover (Figure 4.5.3)

- ND Pattern: Strong rear lobe
- Ab MAX: Near 14) degrees
- GO Pattern: Broad lobe near CPA
- GO MAX: Near CPA

4.7 3ell 206L

Takeoff (Figure 4.7.1)

- ND Pattern: Strong (narrow) trailing lobe,
- Nu MAX: Near 150 degrees
- GO Pattern: Narrow lobe near CPA
- Go MAX: Thear CPA

sopriach (Figure 4.7.2)

- ND Pattern: Broad leading lobe, narrow pronounced trailing lobe
- ND MAX: Near 70 degrees
- GO Pattern: Sharply pointed, moderate lobe
- GJ MAX: Near 70 degrees

Level Flyover (Figure 4.7.3)

- ND Pattern: Strong leading

- NO MAX: Near 30 degrees

- GO Pattern: Broad, slightly leading

- GO MAX: Near 80 degrees

4.8 Hugnes 500C

Takeoff (Figure 4.8.1)

- NO Pattern: Very strong, broad lobe, slightly trailing

- ND MAX: Near 110 degrees

- GO Pattern: Broad lobe centered near CPA

- GO MAX: Near 100 degrees

Approach (Figure 4.8.2)

- ND Pattern: Strong, wide trailing

- ND MAX: Near 140 degrees

- GO Pattern: Medium "teardrop" lobe centered

near CPA

- GO MAX: Near 100 degrees

Level Flyover (Figure 4.8.3)

- ND Pattern: Pronounced leading and trailing lobes

- ND MAX: Near 120 degrees

GO Pattern: Narrow lobe near 110 degrees

- GO MAX: Near 110 degrees

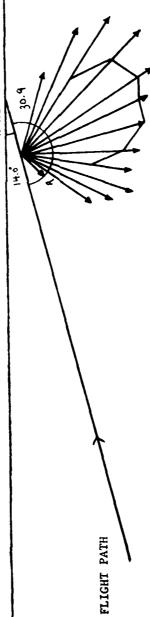
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HELICO: 12	LEST DAIE	JULIER OF LVENTS ALFTA	VECTOR LENGTH REPRESENTS : SCIND LEVEL RELAT

SCALE : lcm = 1d8 outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS -ANGLES INCREASE CLOCKWISE.

HTICOPTER



- 14 -

FIGURE 4.1.1

HELICOPTER DIRECTIVITY ANALYSIS

150 m. East APPROACH REFERENCE SLANT RANGE 500 Feet OPERATION SITE 78.8 REFER OF EVENTS AVERAGED 4 REFER OF LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL -Bell 212 6/15/78 1 COPTER T DATE

SCALE : 1cm = 1dB outside reference semicircle

- 15 -

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

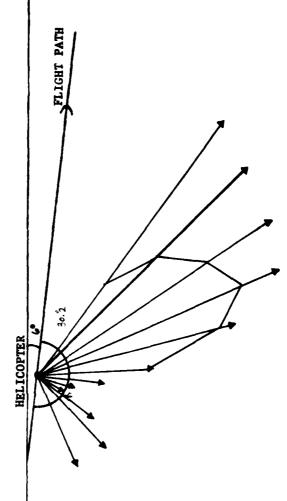


FIGURE 4.1.2

HELLICOLLEX DIRECTIVITY ANALYSIS

OPERATION LEVEL LIVOVET	SITE	KEFEKENCE SLANT RANGE	KELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL =
ELICOVIL STATES	LEST DAIR Paris	NUMBER OF EVENTS AVERAGED	METRIC TO TENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A R

SCALE : lcm = 1dB outside reference schicircle

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FLIGHT PATH

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMEN -ANGLES INCREASE CLOCKWISE.

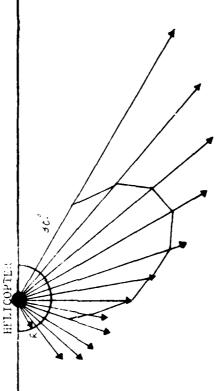


FIGURE 4.1.3

HELICOPTER DIKECTIVITY ANALYSIS

OPERATION Takeoff		REFERENCE SLANT RANGE	db(4) Length Represents the sound level relative to a reference unit vector (r) level = 77.1
HELICOPIER Puma SV-5307	TEST DATE 6/12/78	OF	METRIC (B(A)) VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE 1

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NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

TICOLI FLIGHT PATE

- 17 -

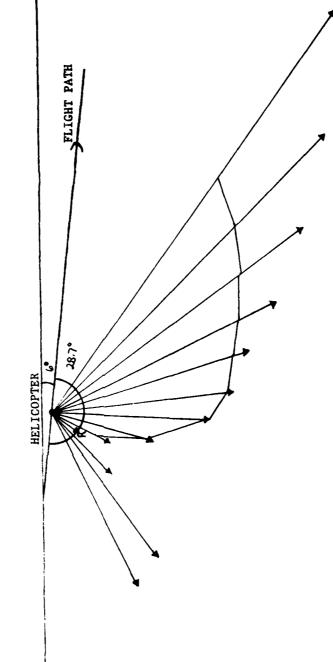
FIGURE 4.2.1

RELICOPTER OTRECTIVITY ANALYSIS

арркоасн	150 m East	500 Feet	
OPERATION APPROACH	SITE	REFERENCE SLANT RANGE 500 Feet	HIT VECTOR (R) LEVEL - 75.
			LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL =
HFLTCOPTER	TEST DATE	NUMBER OF EVENTS AVENCED	METRIC 18(1) VECTOR LENGTH REPRESENTS THE SOUND LEVEL

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.



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FIGURE 4.2.2

HELICOPTER DIRECTIVITY ANALYSIS

HELICOPTER	OPERATION Level Flyover	SITE 150 m East	REFERENCE SLANT RANGE 500 Fect	RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 77.8
HELICOPTER PRESENTS OF A TOTAL STATE OF EVENTS AVERAGED PRETRIC ARCAN REPRESENTS THE SOUND LEVEL				RELATIVE T
HELICOPTER Pura SV 37 8 TEST DATE 6/12/78 NUMBER OF EVENTS AVERAGED METRIC AR(A) VECTOR LENGTH REPRESENTS THE SOUND 1				EVEL
HELICOPTER Purci State TEST DATE 6/12/78 NUMBER OF EVENTS AVERAGED METRIC AR(A) VECTOR LENGTH REPRESENTS THE SO			١	OUND 1
HELICOPTER PURE SV 37 TEST DATE 6/12/78 NUMBER OF EVENTS AVERAGED METRIC dR(A) VECTOR LENGTH REPRESENTS	- ,			CHE S
HELICOPTER TEST DATE NUMBER OF EV METRIC AR	Press St. 37	6/15/28	ENTS AVERAGED	H REPRESENTS
HELICOL TEST DA NUMBER METRIC	PTER .	ATE .	OF EV	LENGT
	HELICO	TEST DA	NUMBER	METRIC

SCALE : |cm = |dB outside reference semicircle

*	7	
٩	1	
ત	1	CM.
•	1	

FLIGHT PATH

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

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- 19 -

FIGURE 4.2.3

HELLCOPIES STRECHTINY ANALYSIN

OPERATION	SITE 150 m East	REFERENCE SLANT RANGE 500 Leet	FINDS LEWILD REFERENCES THE COUND LEVEL RELATIVE TO A NEFERENCE UNIT VECTOR (R) LEVEL = 79.0
. }	:	Page 11	(OUND 1
		Solvadir Sika I de Educ	THE REPORTS
HEL SOUTH	LLOS DATE	Tang Agam.	LINOR TENC

SCALE : Icu = 1dB outside reference semicirele

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

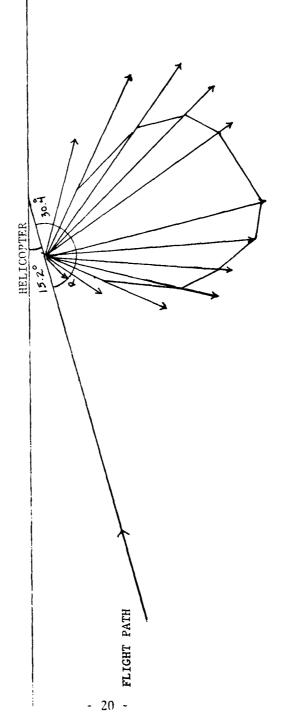


FIGURE 4.3.1

HELLOUPTER DIRECTIVITY ANALYSIS

APPROACH REFERENCE SLANT RANGE 500 Feet OPERATION WICTOR LEGIS ALPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 78.0 NUMBER OF EVENTS AVERAGED UPTER LIT DATE

MALE : | cm = | dB outside reference semicircle

Cm Cm

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

HELICOPTER

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R

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FLIGHT PATH

FIGURE 4.3.2

GROUND LEVEL

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CLAMPIA - 1. .10

Love Brown 150 m last 500 1001 KEFERENCE SLANT MANGE GPERATION CHAIR OF BLIND STREET 113: 10:

CHERT AND A LEASTH REFRESENTS THE SOUND LEVEL NELATIVE IN A PEPERENCE UNIT VECTOR (R) LEVEL = 91.4

SCALE : lcm = ldB outside reference semivirale

FLIGHT PATH

NOTES: " VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTED TO ANOLES INCREASE CLOCKWISE.

29.8

HELICOPTER

- 22 -

FIGURE 4.3.3

HELLCOPTER DIRECTIVITY ANALYSIS

150 m East REFERENCE SLANT RANGE 500 Foot Takeoff OPERATION SITE REFER OF EVENTS AVERAGED " REFER METRIC HEROTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = Sec. 19.19. RELEASE TO THE april 1

SCALE : lcm = ldB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

a and the FLIGHT PATH

- 23 -

FIGURE 4.4.1

GROUND LEVEL

ARLICOPTER DIRECTIVITY ANALISTS

APPROACH 150 n East REFERENCE SLANT RANGE 500 Feet OPERATION SITE .. Š V PERM CY

TOR LEW OF RESTREES THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL =

.JALE : lcm = 1d8 outside reference semicirole

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

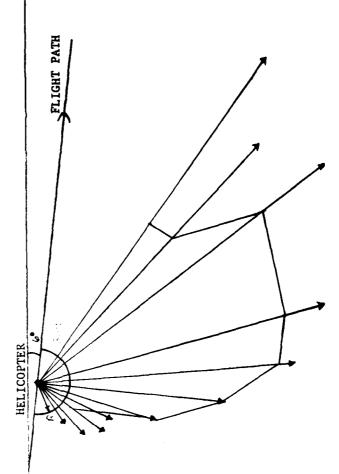


FIGURE 4.4.2

HELLCOPTER DIRECTIVITY ANALYSIS

OPERATION Level Flyover	SITE 150 m East	REFERENCE SLANT RANGE 500 Fect DR (R) LEVEL = 75.3	
HELICOPTER Boolking Rolling	TEST DATE June 12, 1978	NUMBER OF EVENTS AVERAGED A REFERENCE UNIT VECTOR (R) LEVEL = 75.3 VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 75.3	

SCALE : 1cm = 1dB outside reference semicircle

Sm. 5

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE

FLIGHT PATH

HELICOPTER

FIGURE 4.4.3

HELICOPTER DIRECTIVITY ANALYSIS

OPERATION Takeoff	SITE 150 m East	REFERENCE SLANT RANGE 500 Feet	RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = "5".5	
HELICOPHIA CONTRACTOR	TEST DATE	AURER OF EVENTS AVENAGED	VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A	

SCALE : |cm = |dB outside reference semicircle

1 - 1 - 1 - 1 - 1

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

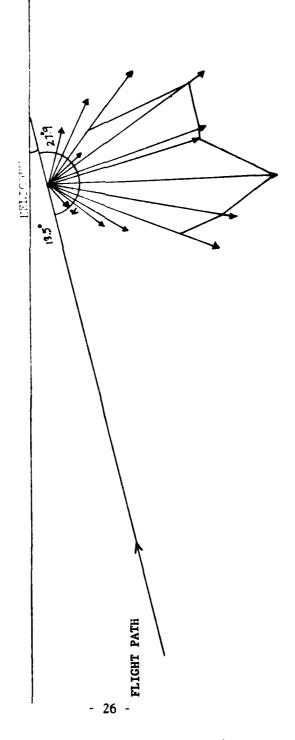


FIGURE 4.5.1

i,

HELLCOPTER DIRECTIVITY ANALYSIS

OPERATION APPROACH	SITE 150 m Fost	REFERENCE SLANT RANGE SOM Feet	RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL - 81.4
RELICOPTEA SINOTSIN (11.55	ST DATE June 15, 1978	TRIC ABOAD	CTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO

at icm = idB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.

HEL LCOPTER

FLIGHT PATH

FIGURE 4.5.2

ABLICOPIE, DISCULL SALVAIS

HELLCOPTER SIKOLSAN CLESS	OPERATION	evel Esover
TEST DATE June 15	SITE	150 m bast
	REFERENCE SLANT RANGE 500 Feet	500 Feet
VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVILL =	83.4	

SCALE : 1cm = 1dB outside reference semicircle

cm.

FLIGHT PATH

NOTES: -VECTURS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS -ALGLES INCREASE CLOCKWISE.

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- 28 -

FIGURE 4.5.3

GROUND LEVEL

NUMBER OF EVENTS AVERAGED $\frac{5}{2}$ METRIC $\frac{\mathrm{dF}(\Lambda)}{\mathrm{dE}(\Lambda)}$ THE SOUND LEVEL RECATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = VECTOR LENGTH REPRESENTS THE SOUND LEVEL RECATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = (arelle 51.5:1) .hme 15, 1973 RELICOPIER TEST DATE

67.4

150 m East

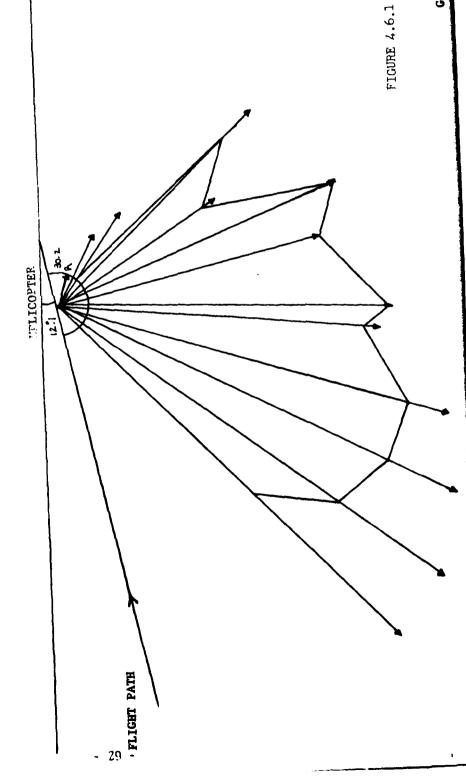
rakeoff

OPERATION

REFERENCE SLANT RANGE 500 Feet

SCALE : 1cm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.



GROUND LEVEL

HELICOPTER DIRECTIVITY ANALYSIS

HLLICOPTER Carelle SV-33 :

of DATE | fare 15, 1978

OPERATION AEPRUACH
SITE 150 to 1381

NEMBER OF EVENTS AVERAGED OF

REFERENCE SLANT RANGE SOF LEET

VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL =

SCALE : lcm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.

HELICOPTER

FLIGHT PATH

FIGURE 4.6.2

CROUND LEVEL

- 30 -

HELICOPTER DIRECTIVITY ANALYSIS

OPERATION LEVEL Flyover	SITE 150 m Fast	REFERENCE SLANT RANGE 500 Feet	RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 75.8
HELICOPTER AND ILL AND THE	TEST DATE June 15, 1:75	NUMBER OF EVENTS AVERAGED	VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELAT

SCALE : 1cm = 1dB outside reference semicircle

* * * * * * * * * * * * * * * * * * * *	CM.

FLIGHT PATH

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

HELICOPTER 28:9

- 31 -

FIGURE 4.6.3

HELICOPIER DIRECTIVEST ANALYSIS

OPERATION Takeoff SITE 150 m Fast	TETRIC 1867H REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = 72.3	<pre>semicircle NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTSANGLES INCREASE CLOCKWISE.</pre>
HELICOPTER Bell 2061. TEST DATE June 16, 1978	NUMBER OF EVENTS AVERAGED METRIC INCLUDIO VECTOR LENGTH REPRESENTS THE SOUND LI	SCALE : lcm * ldB outside reference semicircle

HELICOPTER

FLIGHT PATH

FIGURE 4.7.1

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HELICOPTER DIRECTIVITY ANALYSIS

3c11 2061. NALI COPTER TEST DATE

June 16, 1978

NUMBER OF EVENTS AVERAGED

REFERENCE SLANT RANGE 500 Feet VETRIC AB(A) VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL =

150 m East APPROACH

SITE

OPERATION

SCALE : 1cm - 1dB outside reference semicircle

3

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

FLIGHT PATH

26.9 HELICOPTER

33 -

FIGURE 4.7.2

GROUND LEVEL

HELICOPTER D. E. AND SALYSIS

tevel livover 150 m East REFERENCE SLANT KANGE SOO Feet OPERATION SITE 71.2 NUMBER OF EVENTS AVERAGED OF REPER METRIC (18(1))
WECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A PEFERENCE UNIT VECTOR (R) LEVEL = Re11 2061 June 16, HELICOPTER TEST DATE

SCALE : |cm = 1dB outside reference semicircle

(0 , 2 3 # # CO)

FLIGHT PATH

NOTES: -VECTORS ARE SHOWN IN ALPROXIMATELY 10 DEGREE INCREMENT -ANGLES INCREASE CLOCKWIST.

HELLICOPTER 30°22 FIGURE 4.7.3

GROUND LEVEL

- 34 -

RELYGOPTER DERECTIVITY ANALYSIS

OPERATION Takeoff	SITE 150 n Fast	REFERENCE SLANT RANGE 500 Feet		ELATIVE TO A REFERENCE UNIT VECTOR (R) LEVEL = CARA
	HELLCOPTER SERVICE SOLUTION OF THE PROPERTY OF	TEST DATE uno 16, 1975	NUMBER OF EVENTS AVERAGED	METRIC 38(1) VECTOR LENGTH REPRESENTS THE SOUND LEVEL RELATIVE TO A REFI

SCALE : lcm = ldB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.

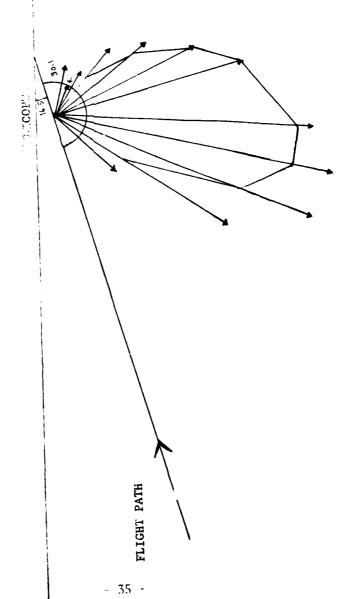


FIGURE 4.8.1

HELLOPPER OF THE AMELYSE

OPERATION

REFERENCE SLANT RANGE STATE

SITE

SELICOPTEA TOUCH STATE

TEST DATE TO SUPPLY TO SUPPLY SUPPLY

TOER OF EVENTS AVERAGED

FELRIC 1 A VICTOR LENGTH REPRESENTS THE CONVERVED RELATIVE OF REFERENCE UNIT VICTOR (A) LEVEL -

SCALE : lcm = 1dB outside reference semicircle

NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS.
-ANGLES INCREASE CLOCKWISE.
HELICOPTER

FLIGHT PATH

HELICOPTER

FIGURE 4.8.2

GROUND LEVEL

- 36 -

HELICOPTEK DIRECTIVITY ANALYSIS

SCALE : 1cm = 1dB outside reference semicircle

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NOTES: -VECTORS ARE SHOWN IN APPROXIMATELY 10 DEGREE INCREMENTS. -ANGLES INCREASE CLOCKWISE.

FLIGHT PATH

- 37 -

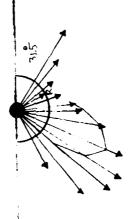


FIGURE 4.8.3

GROUND LEVEL

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